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Direct dimethyl ether high temperature polymer electrolyte membrane fuel cells



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Outline

A high temperature polybenzimidazole (PBI) polymer fuel cell was fed with dimethyl ether (DME) and water vapour mixture on the anode at ambient pressure with air as oxidant. A peak power density of 79 mW/cm² was achieved at 200 °C. A conventional polymer based direct DME fuel cell is liquid fed and suffers from low DME solubility in water. When the DME - water mixture is fed as vapour miscibility is no longer a problem. The increased temperature is more beneficial for the kinetics of the direct oxidation of DME than of methanol. The Open Circuit Voltage (OCV) with DME operation was 50 to 100 mV higher than that of methanol, indicating less fuel crossover.

Dimethyl ether

DME is:

- A clean colourless gas
- Liquid at 6 bar(a)
- - handled like LPG
- Little or not toxic
- Not a greenhouse gas
- - decomposes in atmosphere in tens of hours)

As a fuel:

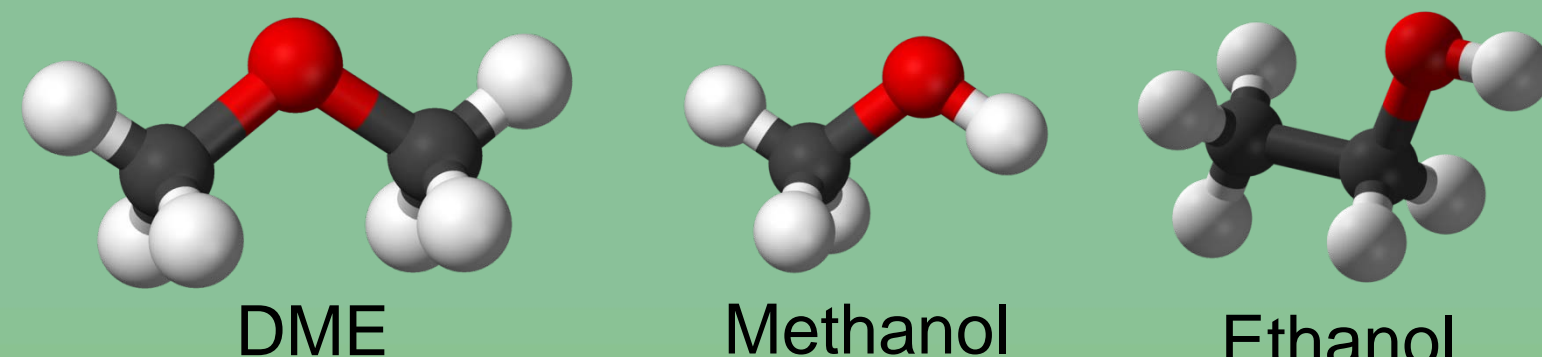
- Cetane rating 55 – 60 (45 for petroleum-derived diesel)
- Burns with no particulate matter (soot)
- Very low NO_x, no SO_x
- Excellent diesel engine fuel

Manufacture:

- From biomass
- From syngas

Other uses:

- Aerosol propellant
- Cooking gas
- Refrigerating agent



	Methane	Methanol	Dimethyl ether	Ethanol	Gasoline	Diesel
Formula	CH ₄	CH ₃ OH	CH ₃ OCH ₃	CH ₃ CH ₂ OH	C ₇ H ₁₆	C ₁₄ H ₃₀
LHV (kJ cm ⁻³)	0.0346	15.82	18.92	21.09	32.05	35.66
LHV (kJ g ⁻¹)	47.79	19.99	28.62	26.87	43.47	41.66
Boil.p (°C)	-162	64	-24.9	78	38-204	125-400



DME powered diesel truck from Volvo

Experimental

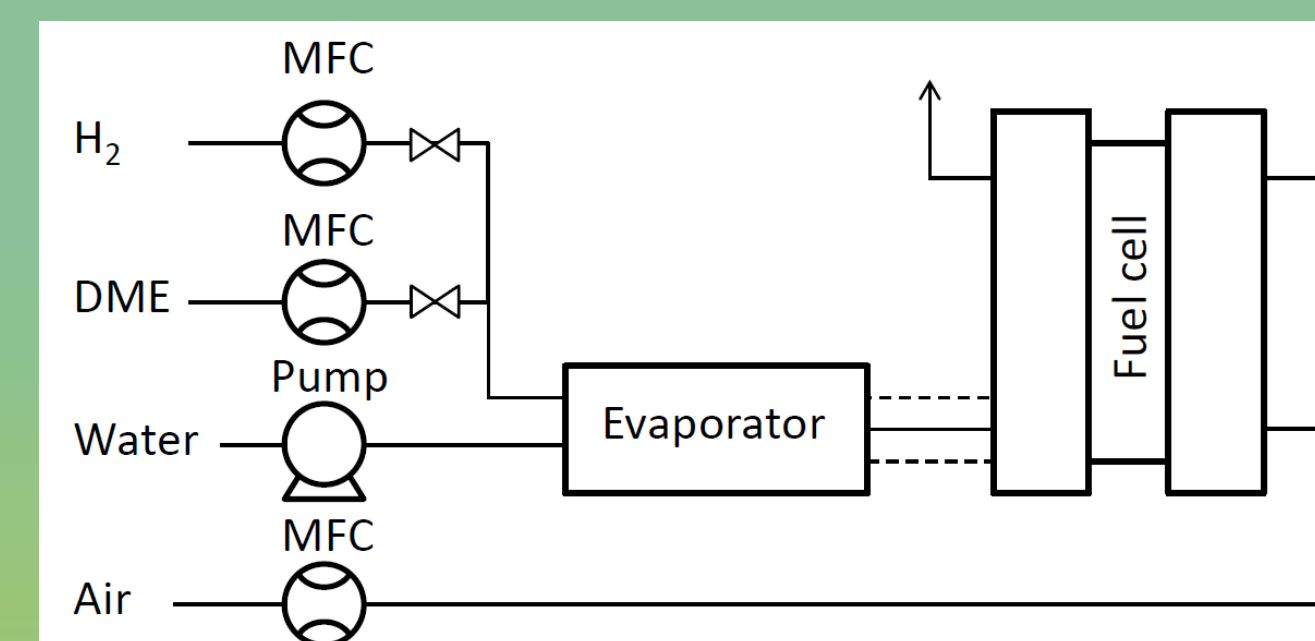
By increasing the working temperature above the boiling point of water and feeding the DME-water mixture as vapour the miscibility is no longer a problem. A phosphoric acid doped PBI system has operation range of 120-200 °C (11,12) and is thus well-suited for the purpose.

MEAs hot-pressed

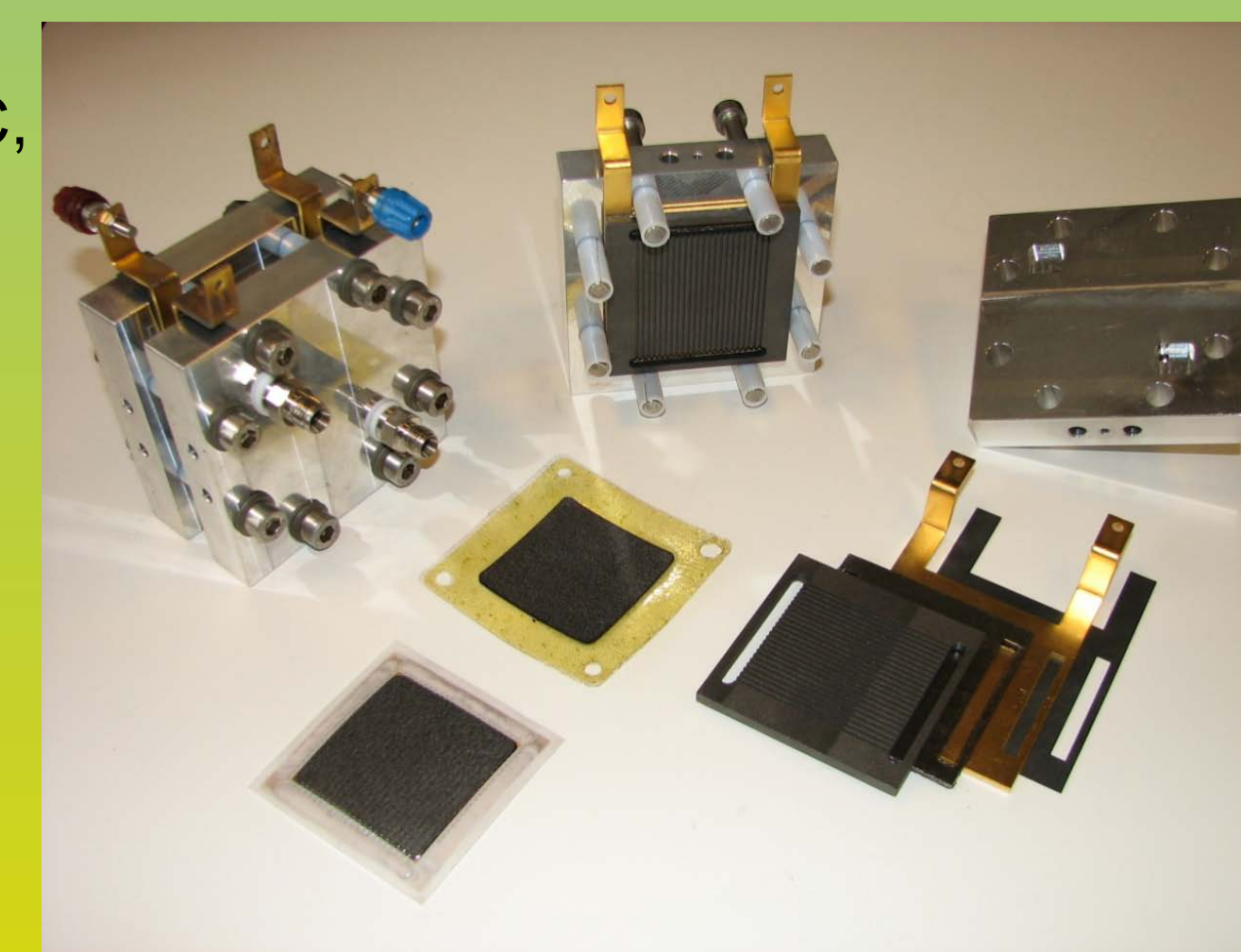
- Anode 40 wt% Pt, 20 wt% Ru, 40 wt% C, Johnson Matthey
- Cathode 60 wt% Pt, 40 wt% C, Johnson Matthey
- Electrolyte 40 µm H₃PO₄-doped PBI membrane, Danish Power Systems
- Protective polysulfone film

Operating conditions

- 150 or 200 °C
- 32 mL/min DME and 0.07 mL/min H₂O
- 0.23 mL/min 1:1 molar MeOH-water



Schematic setup

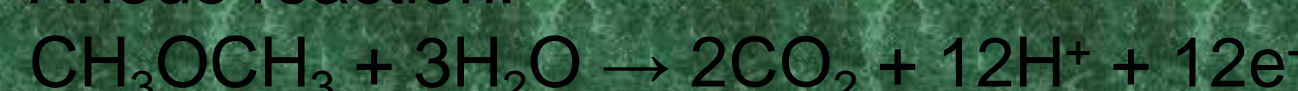


Single cell, MEAs and cell housing.

Direct conversion in a PEMFC

DME is normally fed as an aqueous solution in conventional PEM fuel cells.

Anode reaction:



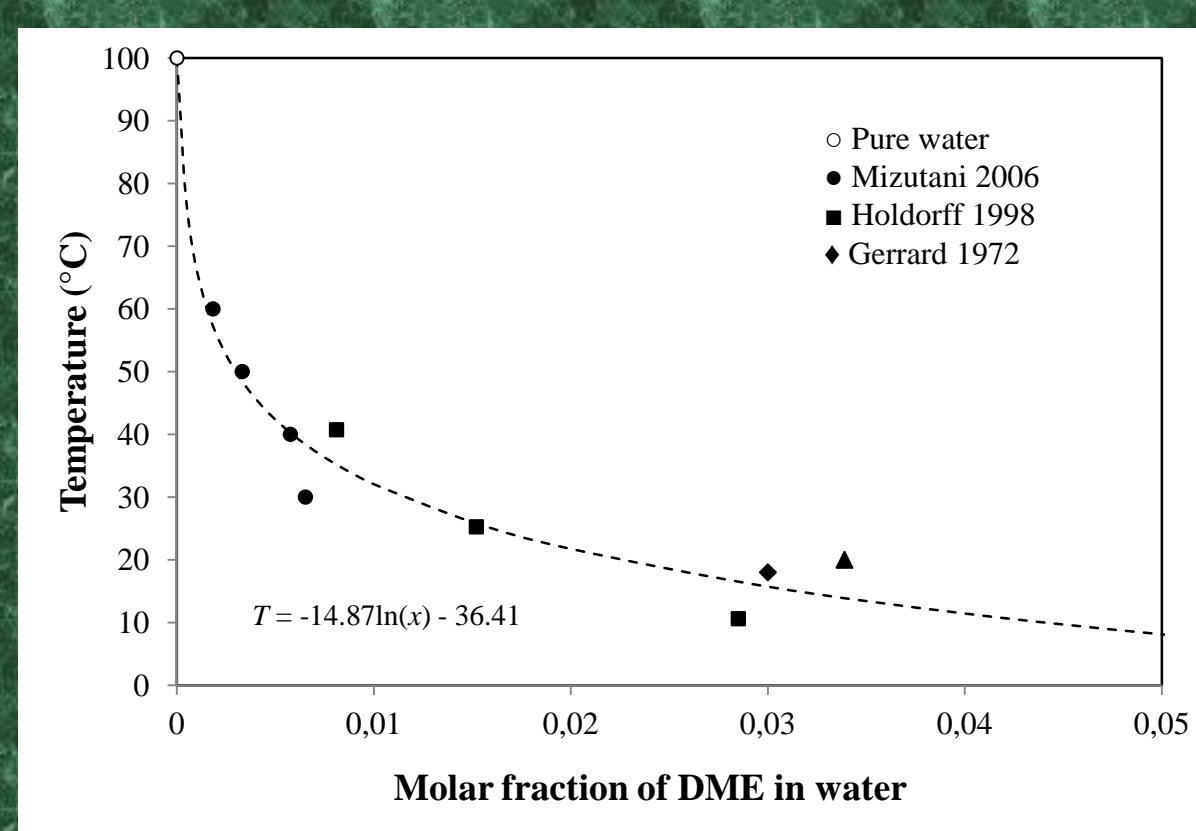
DME-water ratio required 1:3 \Rightarrow 46 wt% solution of DME in water, but DME solubility is only ca. 7.6 wt% at 20°C(2). At 80°C of a traditional polymer fuel cell operation temperature the solubility is even lower and a saturated DME-solution separates into two phases (3). This impedes the process.

Peak power densities reported with conventional polymer fuel cells:

- Ambient pressure, air as oxidant: 20 to 40 mW/cm² (3-5).
- Ambient pressure, pure oxygen: 30 to 56 mW/cm² (6-10).

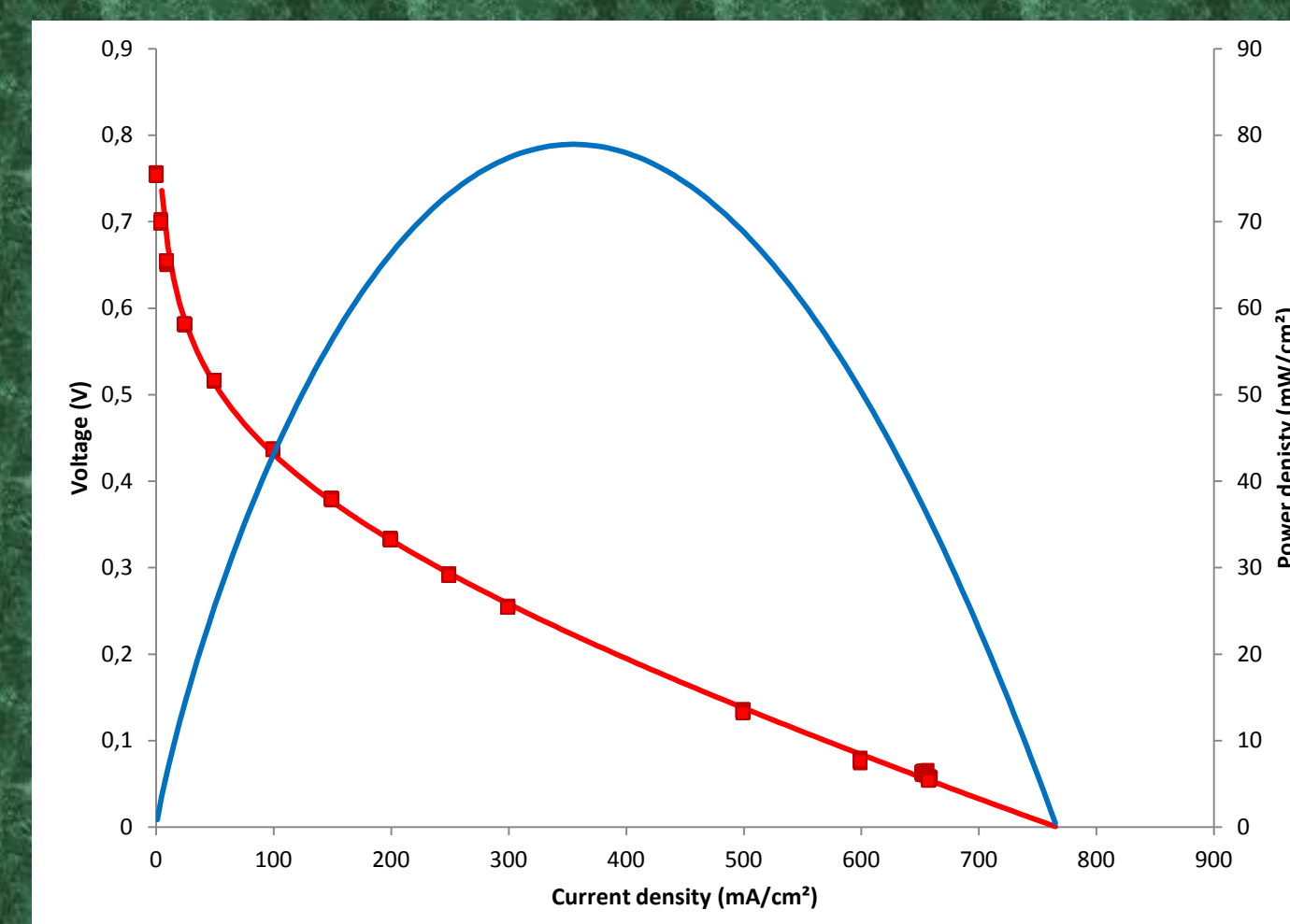
For most applications only air is available. The two-phase problem can be avoided by pressurizing the system, but this consumes energy and is not an attractive option for direct fuel cell systems which are meant to be simple.

One of the major drawbacks of direct methanol fuel cells is the methanol crossover. DME crossover is less pronounced in hydrophilic environment due to the lower dipole moment.



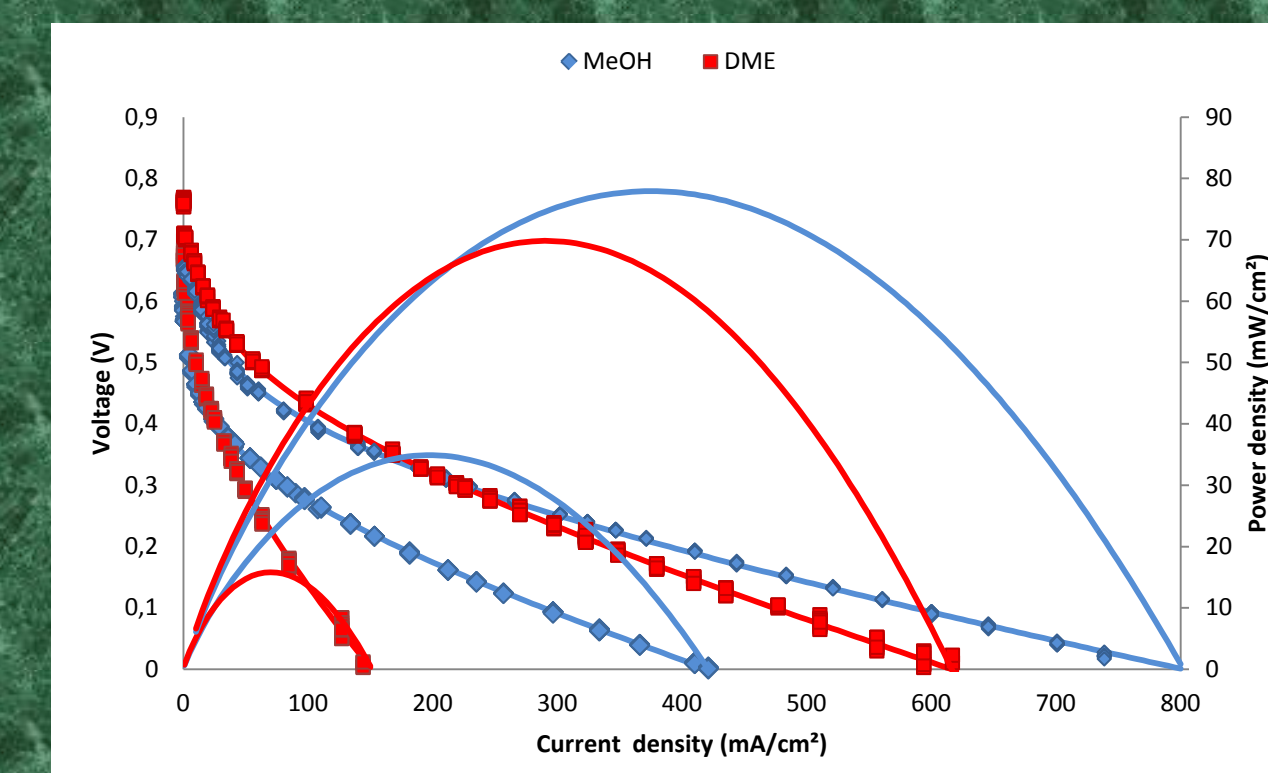
Equilibrium molar fractions of DME in water at different temperatures.

Results

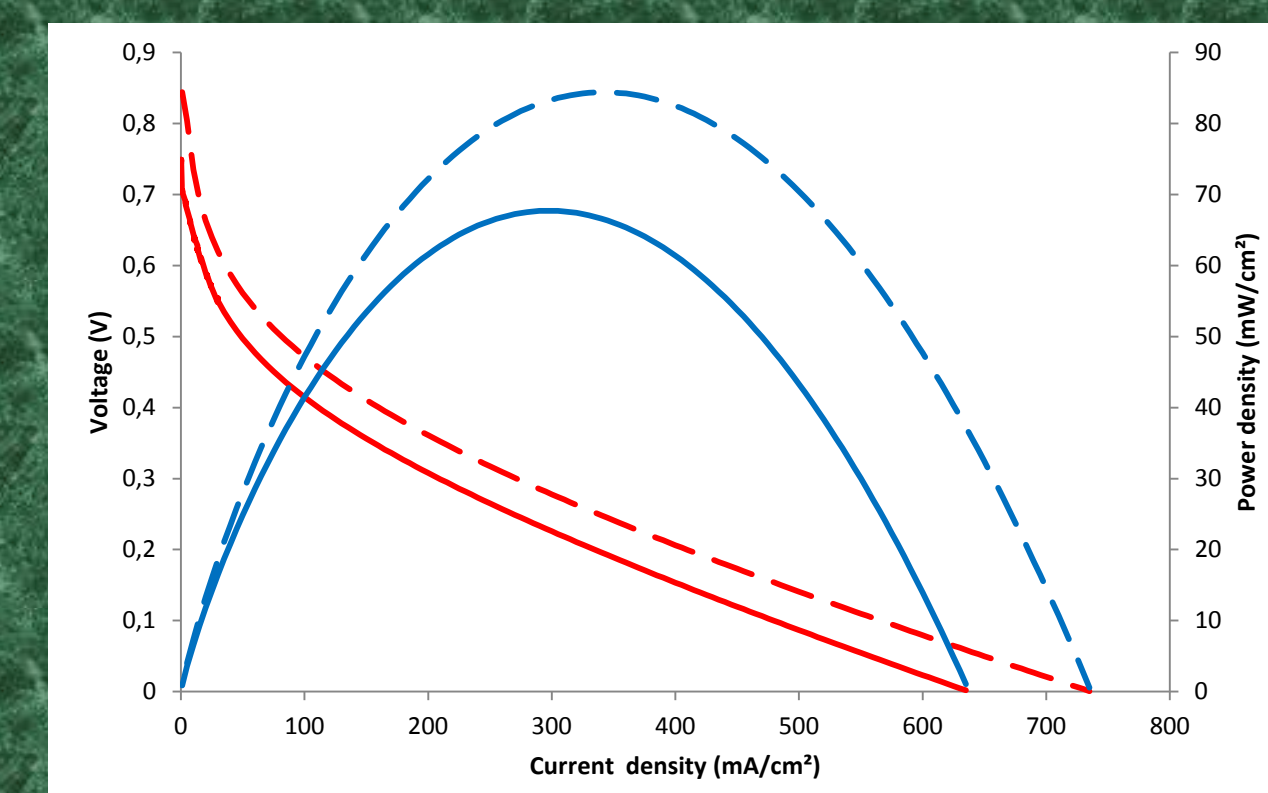


Performance curves of a direct DME fuel cell based on acid doped PBI at 200 °C. Ambient pressure, air as oxidant.

Anode catalyst: PtRu/C (Johnson-Matthey, 1:1, 60 wt%, 4.0 mg metal pr cm²)
Cathode catalyst: Pt/C (Johnson-Matthey, 60 wt%, 0.7 mg Pt pr cm²)



Comparison of direct fuelling with DME and methanol at 150 °C (lower) and 200 °C (upper).



Effect of air (lower) vs. oxygen (upper) at ambient pressure as oxidants on direct DME performance.

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Further on DME:



<http://www.aboutdme.org>

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